MSFC-245

Measurement of Primary Ejecta From Normal Incident Hypervelocity Impact on Lunar Regolith Simulant

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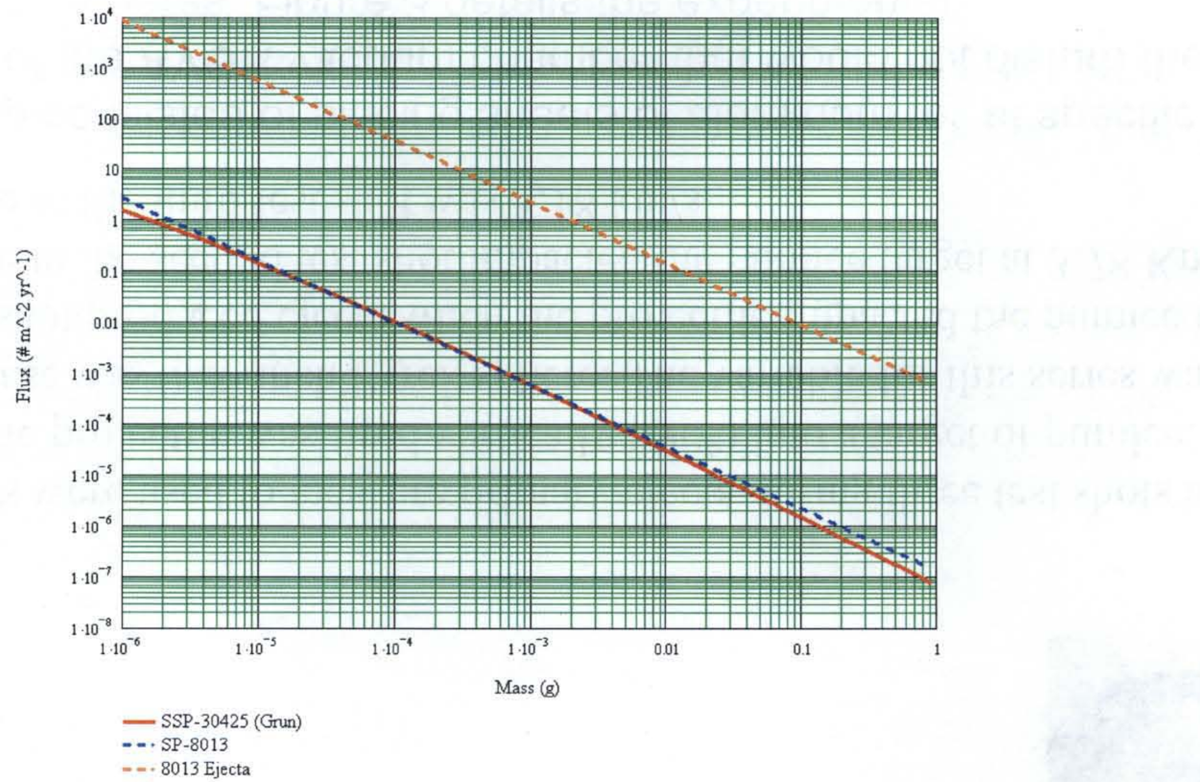
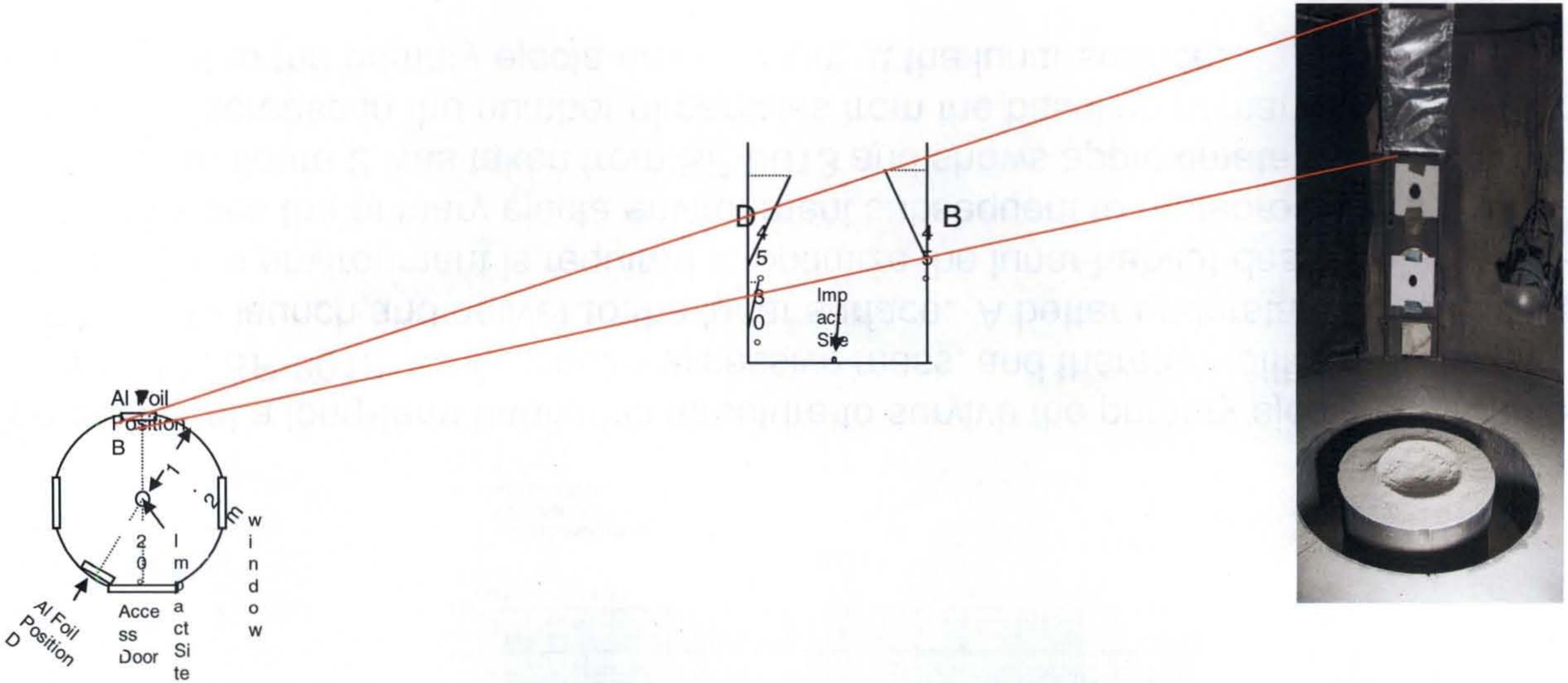
ABSTRACT
The National Aeronautics and Space Administration (NASA) continues to make progress toward long-term lunar habitation. Critical to the design of a lunar habitat is an understanding of the lunar surface environment. A subject for further definition is the lunar primary ejecta environment. The document NASA SP-8013 was developed for the Apollo program and is the latest definition of the primary ejecta environment. There is concern that NASA SP-8013 may over-estimate the lunar primary ejecta environment. NASA's Meteoroid Environment Office (MEO) has initiated several tasks to improve the accuracy of our understanding of the lunar surface primary ejecta environment.
This paper reports the results of experiments on projectile impact into pumice targets, simulating lunar regolith. The Ames Vertical Gun Range (AVGR) was used to accelerate spherical Pyrex projectiles of 0.29g to velocities ranging between 2.5 km/s and 5.18 km/s. Impact on the pumice target occurred at normal incidence. The ejected particles were detected by thin aluminum foil targets placed around the pumice target in a 0.5 Torr vacuum. A simplistic technique to characterize the ejected particles was formulated. Improvements to this technique will be discussed for implementation in future tests.

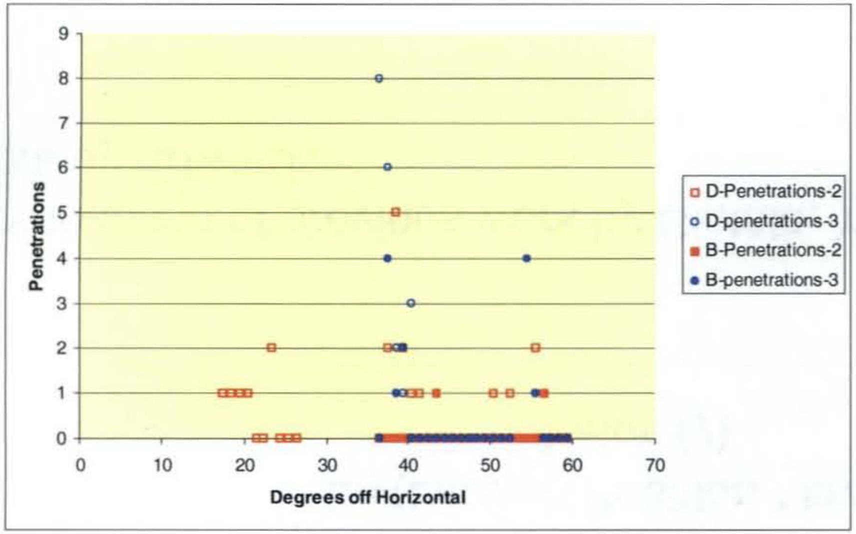


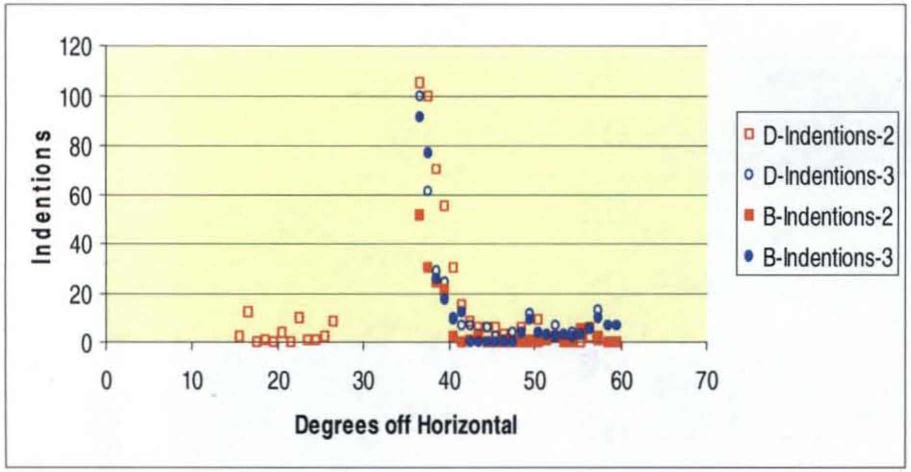
The design of a long-term habitation structure to survive the primary ejecta environment described in SP-8013 would require excessive mass, and therefore difficult and cost-prohibitive to launch and deliver to the lunar surface. A better understanding of the lunar primary ejecta environment is required to optimize the lunar habitat design. NASA SP-8013 describes the primary ejecta environment subsequent to meteoroid impact **D**. The graph in figure 2 was taken from SP-8013 and shows approximately a 4 order of magnitude increase in the number of particles from the baseline primary meteoroid lunar environment to the primary ejecta environment at the lunar surface.



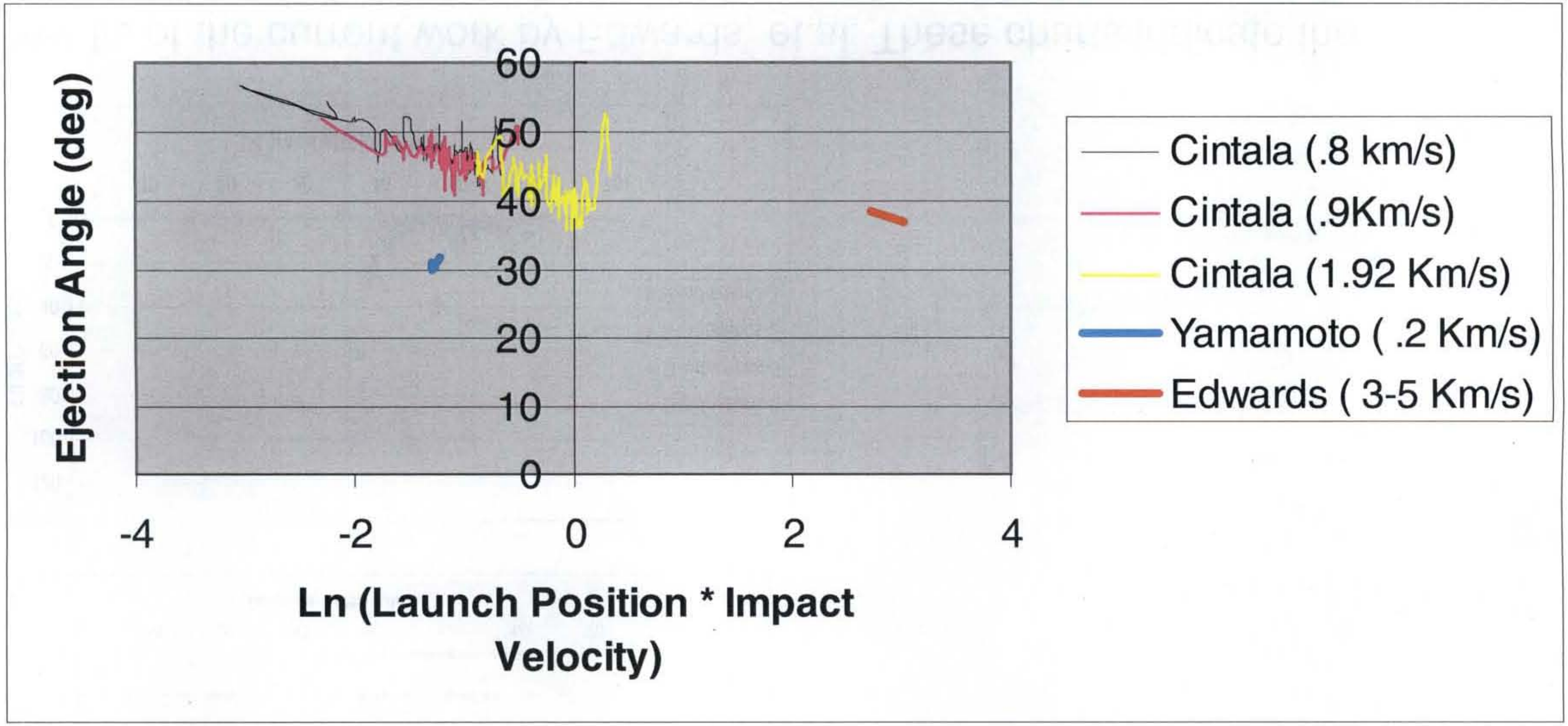
Aluminum foil detectors were used to measure primary ejecta during three test shots at the AVGR. In each case, the projectile was fired vertically (90°) into a target of pumice. The projectile in each case was 0.25 inch Pyrex sphere. The variable for this series was projectile velocity. The first test shot produced ejecta when the projectile impacted the pumice target at 2.5 km/s. The projectile in the second test shot impacted the pumice target at 3.78 Km/s, and the velocity of the projectile in the third test shot was 5.18 km/s.

The experiment set-up consisted of placing sheets of aluminum foil at specific locations around the periphery of the AVGR vacuum chamber that would not disturb the calibration of the video cameras. Figure 3 details the experimental set-up for the three test shots performed. The aluminum foil was 0.0007 inches thick.





Results of the current work by Edwards, et.al. These charts indicate the peak ejection angle for primary ejecta is approximately 38 degrss off the horizontal axis.



Comparison of previous work by Cintala, Yamamoto, and the current work by Edwards.

The Ames Vertical Gun Range (AVGR) was used to accelerate spherical Pyrex projectiles of 0.29g to velocities ranging between 2.5 km/s and 5.18 km/s. Impact on the pumice target occurred at normal incidence. The ejected particles were detected by thin aluminum foil targets placed around the pumice target in a 0.5 Torr vacuum. The results presented in this paper indicate that a peak ejection angle for penetrating primary ejecta is approximately 38° off the horizontal. Previous work by Yamamoto resulted in a peak ejection angle of approximately 30°. Yamamoto et al used a "staple-shaped copper projectile with impact velocities ranging from 243 to 272 m/s and impacted a target consisting of soda-lime particles with a nominal diameter of 220 μm. Cintala et al performed a series of impact tests using spherical aluminum particles accelerated to velocities ranging from 0.8 to 1.92 Km/s. The incident projectiles had a nominal diameter of 4.76 mm and impacted coarse-grained sand with grain sizes ranging from1-3 mm. Cintala provides extensive detail for characterizing the ejecta distributions and recorded ejecta angles ranging between 38° and 55°. Cintala, Yamamoto and Edwards used varying techniques to determine ejecta distributions, with Cintala and Yamamoto also providing ejecta velocities. This paper presented an attempt to normalize existing data on ejecta angular distributions in an attempt to capitalize on previous results to aid in enhancing the primary ejecta environment on the lunar surface and thus reduce the cost of defining this specific environment for the design of future lunar missions.
More work is needed to better characterize this ejecta environment, and more test are planned, utilizing various regolith compounds. In addition, improved detection techniques will be employed including sheet lasers, various thickness's of aluminum foils, and variation of the foil distance to the impact site.